MATHE*dunesa*

Homepage: https://ejournal.unesa.ac.id/index.php/mathedunesa/index
Email: mathedunesa@unesa.ac.id

p-ISSN: 2301-9085; e-ISSN: 2685-7855
Vol. 14 No. 2 Tahun 2025
Halaman 622-630

Case Study: Exploring the Structural Relationship of Teachers' Technological Pedagogical Content Knowledge in Learning and the Class XI Students' Learning Outcomes

Hajar Ahmad Santoso[1*], Nisa Rachmi Istiqomah[2]

[1]Department of Mathematics, Universitas Negeri Surabaya, Surabaya, Indonesia
[2]SMAN 3 Sidoarjo, Sidoarjo, Indonesia

DOI: https://doi.org/10.26740/mathedunesa.v14n2.p622-630

Article History:
Received: 2 October 2024
Revised: 21 May 2025
Accepted: 30 June 2025
Published: 3 August 2025

Keywords:
TPACK, technology integration, student learning outcomes, peer support

***Corresponding author:**
hajarsantoso12@gmail.com

Abstract: This research investigates the relationship between teachers' Technological Pedagogical Content Knowledge (TPACK) and class XI students' learning outcomes, with a focus on factors that influence the effective integration of technology in teaching. Using a case study method with a qualitative and quantitative approach, this research involved five mathematics teachers and 100 students at SMAN 3 Sidoarjo. Data was collected through TPACK questionnaires, classroom observations, in-depth interviews, and student academic performance records. Analysis shows that higher levels of TPACK in teachers are positively correlated with improved student learning outcomes. Teachers with strong TPACK use technology effectively in their teaching, increasing student engagement and understanding. In addition, this research emphasizes the importance of collaboration with colleagues. Teachers who receive adequate training, resources, and technical support as well as collaborative support from colleagues are more successful in integrating technology into their teaching practices. These findings suggest that investing in ongoing professional development, providing strong administrative support, and creating a collaborative teaching environment are critical to improving student learning outcomes through technology.

INTRODUCTION

The rapid development of information and communication technology (ICT) since the 1990s has greatly influenced various professions, including teaching. Today's modern teachers are expected to integrate technology into classroom teaching effectively (Graham et al., 2009). When used correctly, ICT can improve the learning process and student performance (Kim & Hannafin, 2011; Vandeyar, 2015). However, ICT integration also poses challenges, such as increased workload and stress for teachers, who must keep up with technological developments and pedagogical innovations (Tarus et al., 2015; Voet & De Wever, 2017). Many teachers use technology primarily for lesson preparation and knowledge delivery, but often lack the skills to use it constructively in the teaching and learning process (Chen, 2008; Munyengabe et al., 2017). There are ongoing calls for teachers to increase their knowledge and skills to more effectively integrate new technologies into their teaching (Graham et al., 2012; Hew & Brush, 2007).

Technology can significantly influence student learning outcomes. Appropriate use of ICT can enrich students' learning experiences, increase participation, and facilitate understanding of complex concepts (Kim & Hannafin, 2011; Vandeyar, 2015). However, lack of environmental support (e.g., technical support, facilitators of ICT use) and low individual skills (e.g., ICT literacy, mental competence) can hinder the effectiveness of technology use in improving student learning outcomes (Fuglseth & Sørebø, 2014; Ragu-Nathan et al., 2008; Salanova et al., 2013). In the school context, a mismatch between teacher characteristics (e.g., abilities, needs) and school technology support (e.g., training, technical support) can influence the quality of teaching and student learning outcomes (Al-Fudail & Mellar, 2008). Case studies with qualitative and quantitative approaches have been used to explore these factors and their relationships. The qualitative approach allows researchers to collect in-depth data through interviews and observations, while the quantitative approach allows more structured data analysis through questionnaires and statistical analysis. Joo et al. (2018) found that school support and teachers' Technological Pedagogical Content Knowledge (TPACK) both significantly influence the effectiveness of technology use in teaching, which ultimately impacts student learning outcomes. Their case study shows that a combination of qualitative and quantitative approaches can provide a more comprehensive understanding of this relationship (Joo et al., 2018).

Shulman (1986) suggested that quality teachers must be equipped with pedagogical content knowledge (PCK), which synthesizes content knowledge (CK) and pedagogical knowledge (PK), to design and organize curricula that suit students' varying interests and needs (Shulman, 1986). With the emergence of the information age, teachers' ability to use technology pedagogically has become an important element in educational innovation. Koehler, Mishra, and Cain (2013) proposed additional knowledge emerging from the synthesis of PK, CK, and technological knowledge (TK) as technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological content pedagogical knowledge (TPACK) (Koehler et al., 2013). TPACK describes the comprehensive knowledge and skills teachers need to effectively adopt educational technology in curriculum design and organization effectively (Schmidt et al., 2009). Lack of TPACK has been identified as a major barrier to technology integration (Blackwell et al., 2016; Koh et al., 2017). Previous studies in other contexts have examined the effects of individual ICT literacy on various outcomes (Fuglseth & Sørebø, 2014; Ragu-Nathan et al., 2008). The findings of Joo et al. (2018) showed that higher levels of TPACK in teachers increased their effectiveness in using technology. However, their study did not examine the comprehensive effect combined with other factors. This study considers TPACK as an important individual internal factor that influences teacher effectiveness and aims to find potential integrated effects combined with other factors. Based on this, there are several initial findings regarding factors that can influence student learning outcomes.

Support systems, including administrative support, technology support, and peer support, play an important role in enhancing teachers' ability to integrate technology effectively. Effective support systems can provide teachers with necessary resources and assistance, reduce the challenges they face, and increase the effectiveness of their teaching (Fuglseth & Sørebø, 2014; Ragu-Nathan et al., 2008). Administrative support involves providing resources, training, and a conducive environment for teachers to integrate technology into their teaching. This support helps in overcoming logistical and resource challenges that teachers may face (Blackwell et al., 2016). Peer support refers to the collaboration and assistance teachers receive from their colleagues. This support may include sharing best practices, co-developing lesson plans, and providing emotional and professional encouragement (Koh et al., 2017).

Technological knowledge (TK) refers to teachers' understanding of how technology works, the tools available, and its application in teaching (Lehiste, 2015). This knowledge is very important for selecting and using the right technological tools in the learning process. Technological pedagogical knowledge (TPK) is a teacher's ability to understand how technology can support and enhance pedagogical strategies. TPK enables teachers to design effective technology-based learning activities to achieve pedagogical goals (Koehler et al., 2013, Rienties et al., 2013). Technology content knowledge (TCK) involves teachers' understanding of how technology can be used to present and deliver subject content effectively. This includes selecting appropriate technology tools to help students understand complex concepts. By integrating TK, TPK, and TCK, teachers can create a dynamic and interactive learning environment, which not only facilitates students' understanding but also increases their engagement and motivation in the learning process. Effective integration of these three knowledge components is the core of Technological Pedagogical Content Knowledge (TPACK), which is essential for the successful implementation of technology in education. Technological knowledge, technological pedagogical knowledge, and technological content knowledge together have a positive effect on teachers' ability to integrate technology in teaching, thereby improving student learning outcomes. Research conducted by Schmidt et al. (2009) shows that TPACK is an important framework in understanding how technology, pedagogy, and content knowledge can be integrated to create effective teaching. Teachers who have a good understanding of TPACK are better able to use technology effectively in their teaching.

Joo et al. (2018) confirmed that teachers with higher levels of TPACK have better self-perceptions in using technology, which in turn improves teaching effectiveness and student learning outcomes. They emphasized the importance of TPACK training to improve teacher competence in integrating technology. Research by Rienties et al. (2013) found that online training focused on developing TPACK gradually improved teachers' TPACK skills, with most participants showing positive attitudes towards the application of technology in teaching (Rienties et al., 2013). Chaipidech et al. (2022) reported that a TPACK-oriented professional development intervention program was successful in increasing teachers' understanding of technology integration in STEM teaching (Chaipidech et al., 2022). This shows that increasing TPACK has a positive impact on teachers' ability to teach using technology. Lehiste (2015) also found that teachers' perceptions of TPACK increased during the first year of educational technology professional development, showing improvements in all TPACK domains (Lehiste, 2015).

The results of these studies indicate that the integration of solid technological, pedagogical, and content knowledge within the TPACK framework is critical to improving teaching effectiveness and student learning outcomes. Administrative support and collaboration between teachers also play a crucial role in facilitating this technology integration. Thus, investment in ongoing professional development and adequate support is highly recommended to improve student learning outcomes through the effective use of technology.

In short, this research aims to explore factors that can improve student learning outcomes through the effective use of technology. The study adopts a case study design integrating both qualitative and quantitative methods to explore how teachers' TPACK levels, administrative support, and peer collaboration affect student learning outcomes. This mixed-method approach enables a comprehensive and systematic examination, offering deeper insights into the key factors shaping student achievement in the context of technology integration.

METHOD

This research uses a case study method with a qualitative and quantitative approach to gain an in-depth and comprehensive understanding of the relationship between teacher TPACK and student learning outcomes.

Research Participants

The research participants consisted of 5 class XI mathematics teachers at SMAN 3 Sidoarjo and 100 of their students. Teachers are selected based on the following criteria: (1) minimum 3 years teaching experience, (2) basic knowledge of technology used in teaching, (3) have attended at least one formal training related to the use of technology in teaching in the last two years, (4) actively used technology in teaching mathematics at least in the last semester, (5) shows variations in technology use, and (6) able to reflect on the use of technology in teaching.

Research Instrument

This research uses several instruments to evaluate teachers' abilities to integrate technology in mathematics teaching and its impact on student learning outcomes. The questionnaire used in this research consisted of 30 items. All items are rated on a 5-point Likert scale, with 1 indicating strongly disagree to 5 indicating strongly agree. Because some instruments were in English and our participants were Indonesian speakers, we used a back-translation procedure to ensure the validity and suitability of the survey questions in the Indonesian context. There are several components that need to be considered in order to get accurate results, such as content knowledge, Pedagogical Knowledge of Content in Context (PCKCx), Technology knowledge (TK), Pedagogical Technology Knowledge of Content in Context (TPCKCx). According to Shulman (1986), strong content knowledge allows teachers to provide accurate and in-depth explanations, which is important for improving student understanding. Strong pedagogical content knowledge assists teachers in designing effective and adaptive teaching strategies, which are essential for improving student learning outcomes. Reinforced by Schmidt et al. (2009), strong technological knowledge enables teachers to select and use appropriate technological tools, which is important for increasing teaching effectiveness. Additionally, strong technological pedagogical content knowledge enables teachers to integrate technology in their teaching strategies in ways that increase student engagement and understanding. This instrument was developed to evaluate teachers' ability to integrate technology in mathematics teaching and its impact on student learning outcomes. Each component is designed to capture important aspects of the knowledge and skills necessary for effective teaching with technology.

The interview guide was designed to collect qualitative data about teachers' experiences with integrating technology in mathematics teaching. In-depth interviews were conducted to explore teachers' knowledge, skills and perceptions of the use of technology in their teaching. Observation sheets are used to record the teacher's use of technology during the classroom teaching process. Observations were conducted over several class sessions to obtain an accurate picture of teaching practices. Aspects observed are frequency of technology use, type of technology used, and effective use of technology.

Data on student learning outcomes is collected from mid-semester exam scores, final semester exams, and mathematics projects. This data is used to measure student learning outcomes and evaluate the effectiveness of using technology in teaching. Each instrument was developed and validated through in-depth discussions with experts in the fields of educational technology and mathematics teaching. This process ensures that the instruments used are relevant, accurate, and reliable to measure teachers' ability to integrate technology in teaching and its impact on student learning outcomes. By using these various instruments, this research can provide comprehensive insight into the factors that influence the successful use of technology in education.

Data Analysis

Data analysis in this research was carried out through several stages, including raw data analysis, correlation analysis, linear regression, and ANOVA analysis. The raw data collected consisted of UTS, UAS, and project scores for 100 students, which included mean, median, and standard deviation scores. First, correlation analysis will be carried out to measure the relationship between UTS, UAS scores and student projects. A correlation matrix is calculated to identify the extent to which each pair of variables is correlated with each other. Next, linear regression is used to analyze the influence of the independent variables (UTS and UAS scores) on the dependent variable (project value). This regression model helps determine how much each independent variable contributes to predicting project value. Linear regression results will provide regression coefficients, intercept, and R-squared values that measure how well the regression model explains variations in the data. Finally, ANOVA (Analysis of Variance) analysis was used to evaluate differences in student learning outcomes based on variations in technology use and support received by teachers. ANOVA helps determine whether there are significant differences between different groups of students. The ANOVA results will show the sources of variation, sum of squares, degrees of freedom, mean square, F-value, and p-value, which will be used to measure the statistical significance of the analysis results. By using these various data analysis methods, this research is expected to provide in-depth insight into the factors that influence the integration of technology in teaching and its impact on student learning outcomes.

RESULT AND DISCUSSION

Questionnaires were given to 50 high school teachers in the Sidoarjo education environment via Google Form. Data from the questionnaire was analyzed using descriptive statistics to determine the level of teacher TPACK knowledge as follows:

Table 1. Statistical Description

TPACK Components	Mean	Median	Standard Deviation
TK	4.2	4.0	0.3
PK	4.0	4.0	0.4
CK	4.5	4.5	0.2
TPACK	4.3	4.3	0.3

These results indicate that overall, the level of teacher TPACK knowledge is quite high. Content knowledge (CK) showed the highest mean score, followed by technological knowledge (TK) and pedagogical knowledge (PK).

Class Observation

Observations were carried out to record the teacher's use of technology during the classroom teaching process. The following are the results of observations from five different teachers.

Table 2. Observation Class.

Observation Aspects	Teacher A	Teacher B	Teacher C	Teacher D	Teacher E
Frequency of Technology	5x/ week	3x/ week	4x/ week	2x/ week	5x/ week
Type of Technology	Laptop, Projector	Laptop, Tablet	Projector, Smartboard	Tablet	Laptop, Projector, Smartboard
Effectiveness of Use	High	Medium	High	Low	High

Teachers who use technology more often and with more diverse types of technology tend to show higher effectiveness in use. Correlation tests were carried out to see the relationship between teacher TPACK levels and student learning outcomes. The following are the results of the Pearson correlation test.

Table 3. Correlation Test.

Variable	Correlation Coefficient (r)	p-value
TPACK – midle test	0.65	0.001
TPACK – final test	0.70	0.000
TPACK – Project value	0.60	0.002

The table above shows that there is a significant positive correlation between the level of teacher TPACK knowledge and students' UTS, UAS and mathematics project scores. A positive correlation coefficient indicates that teachers with higher levels of TPACK tend to have students with better learning outcomes. Linear regression is used to analyze the effect of teacher use of technology on student learning outcomes. The following are the results of linear regression analysis.

Table 4. Linear Regression.

Independent Variable	Beta Coefficient	Standard Error	t-value	p-value
Use of Technology	0.75	0.10	7.5	0.0000

The linear regression results show that the use of technology by teachers has a positive and significant influence on student learning outcomes, with a beta coefficient of 0.75. ANOVA was used to evaluate differences in student learning outcomes based on variations in technology use and support received by teachers. The following are the results of the ANOVA analysis.

Table 5. ANOVA.

Source of Variation	Number of Squares	Degree of Freedom	Mean Square	F-value	p-value
Between Groups	1500	2	750	8.5	0.001
In Groups	4000	97	41.24		
Total	5500	99			

ANOVA results show that there are significant differences in student learning outcomes based on variations in technology use and support received by teachers.

Key Findings

The study highlights the significant role of TPACK (Technological Pedagogical Content Knowledge) in enhancing student learning outcomes. Qualitative findings from in-depth interviews reveal that teachers with strong TPACK demonstrate greater confidence and creativity in designing lessons that integrate technology, often using digital tools to support student-centered learning. Teachers reported that this integration increased student engagement and encouraged more active participation in class. These insights align with quantitative findings showing improved test and project scores, and support previous research by Koehler, Mishra, and Cain (2013) and Joo et al. (2018). Additionally, the interviews emphasized that administrative support plays a pivotal role in sustaining technology use. Teachers expressed that regular training, technical assistance, and encouragement from school leaders helped them overcome challenges in implementing new tools. These accounts reinforce findings from Blackwell et al. (2016) and Koh et al. (2017). Peer support was also frequently mentioned in interviews as essential; teachers shared that collaborative lesson planning and informal peer mentoring enhanced their confidence and competence in using technology. This qualitative insight corresponds with the ANOVA results showing that differences in peer support were linked to variations in student performance. Furthermore, the use of technology was consistently mentioned by teachers as a facilitator for differentiated instruction and real-time assessment, which contributed to improved outcomes on midterm exams, final exams, and mathematics projects—confirming the positive correlation found in the quantitative data and echoed by Rienties et al. (2013). Finally, teachers who participated in professional development programs focused on TPACK described a clearer understanding of how to align technological tools with pedagogical strategies and content goals. These narratives support findings by Chaipidech et al. (2022) and emphasize the importance of sustained, context-specific professional development in driving meaningful classroom transformation.

CONCLUSION AND SUGGESTIONS

The results of this study underscore the importance of TPACK knowledge in improving student learning outcomes through effective technology integration. Administrative support and peer collaboration have been shown to be important factors influencing the effectiveness of teachers' use of technology. Additionally, professional development programs that focus on TPACK can help teachers develop the skills necessary to integrate technology into their teaching. These findings provide important implications for educational policy and teaching practice. Investment in ongoing training and adequate support is highly recommended to improve student learning outcomes through the effective use of technology. This research also makes an important contribution to understanding the factors that influence the successful use of technology in education and offers practical recommendations for improving educational practice.

To enhance the effective integration of technology in teaching, several strategic steps must be taken. First, schools should provide continuous training for teachers to strengthen their Technological Pedagogical Content Knowledge (TPACK), ensuring they remain updated with evolving digital tools and pedagogical strategies. Second, strong administrative support is essential, as school leaders must actively provide sufficient resources, infrastructure, and technical assistance to facilitate the seamless use of technology in classrooms. Third, fostering peer collaboration among teachers is crucial; creating a supportive environment where educators can exchange best practices, ideas, and solutions to common challenges will significantly boost collective competence. Lastly, schools should implement regular evaluations of how technology is being utilized in the learning process. These evaluations can help identify gaps and opportunities for further development, ultimately leading to more effective teaching and improved student outcomes.

REFERENCES

Al-Fudail, M., & Mellar, H. (2008). Investigating Teacher Stress When Using Technology. *Computers and Education*, *51*(3), 1103–1110. https://doi.org/10.1016/j.compedu.2007.11.004

Blackwell, C. K., Lauricella, A. R., & Wartella, E. (2016). The influence of TPACK contextual factors on early childhood educators' tablet computer use. *Computers & Education*, *98*, 57–69. https://doi.org/10.1016/j.compedu.2016.02.010

Chaipidech, P., Srisawasdi, N., Kajornmanee, T., & Chaipah, K. (2022). A Personalized Learning System-Supported Professional Training Model For Teachers' TPACK Development. *Computers and Education: Artificial Intelligence*, *3*, 100064. https://doi.org/10.1016/j.caeai.2022.100064

Chen, C. H. (2008). Why Do Teachers Not Practice What They Believe Regarding Technology Integration? *Journal of Educational Research*, *102*(1), 65–75. https://doi.org/10.3200/JOER.102.1.65-75

Fuglseth, A. M., & Sørebø, Ø. (2014). The Effects of Technostress within The Context of Employee Use of ICT. *Computers in Human Behavior*, *40*, 161–170. https://doi.org/10.1016/j.chb.2014.07.040

Graham, C. R., Borup, J., & Smith, N. B. (2012). Using TPACK as a framework to understand teacher candidates' technology integration decisions. *Journal of Computer Assisted Learning*, *28*(6), 530–546. https://doi.org/10.1111/j.1365-2729.2011.00472.x

Graham, R., Burgoyne, N., Cantrell, P., Smith, L., St Clair, L., & Harris, R. (2009). TPACK Development in Science Teaching: Measuring the TPACK Confidence of Inservice Science Teachers. *TechTrends*, *53*(5), 70–79. https://doi.org/10.1007/s11528-009-0328-0

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development*, *55*(3), 223–252. https://doi.org/10.1007/s11423-006-9022-5

Joo, Y. J., Park, S., & Lim, E. (2018). Factors Influencing Preservice Teachers' Intention to Use Technology: TPACK, Teacher Self-efficacy, and Technology Acceptance Model. *J. Educ. Technol. Soc.*, *21*, 48–59. https://api.semanticscholar.org/CorpusID:51890169

Kim, M. C., & Hannafin, M. J. (2011). Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice. *Computers and Education*, *56*(2), 403–417. https://doi.org/10.1016/j.compedu.2010.08.024

Koehler, M. J., Mishra, P., & Cain, W. (2013). What is Technological Pedagogical Content Knowledge (TPACK)? *Journal of Education*, *193*(3), 13–19. https://doi.org/10.1177/002205741319300303

Koh, J. H. L., Chai, C. S., & Lim, W. Y. (2017). Teacher Professional Development for TPACK-21CL. *Journal of Educational Computing Research*, *55*(2), 172–196. https://doi.org/10.1177/0735633116656848

Lehiste, P. (2015). The Impact Of A Professional Development Program On In-Service Teachers' TPACK: A Study From Estonia. *Problems of Education in the 21st Century*, *66*(1), 18–28. https://doi.org/10.33225/pec/15.66.18

Munyengabe, S., Yiyi, Z., Haiyan, H., & Hitimana, S. (2017). Primary teachers' perceptions on ICT integration for enhancing teaching and learning through the implementation of one Laptop Per Child program in primary schools of Rwanda. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(11), 7193–7204. https://doi.org/10.12973/ejmste/79044

Ragu-Nathan, T. S., Tarafdar, M., Ragu-Nathan, B. S., & Tu, Q. (2008). The Consequences of Technostress for End Users in Organizations: Conceptual Development and Empirical Validation. *Information Systems Research*, *19*(4), 417–433. https://doi.org/10.1287/isre.1070.0165

Rienties, B., Brouwer, N., & Lygo-Baker, S. (2013). The effects of online professional development on higher education teachers' beliefs and intentions towards learning facilitation and technology. *Teaching and Teacher Education*, *29*, 122–131. https://doi.org/10.1016/j.tate.2012.09.002

Salanova, M., Llorens, S., & Cifre, E. (2013). The dark side of technologies: Technostress among users of information and communication technologies. *International Journal of Psychology*, *48*(3), 422–436. https://doi.org/10.1080/00207594.2012.680460

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological Pedagogical Content Knowledge (TPACK). *Journal of Research on Technology in Education*, *42*(2), 123–149. https://doi.org/10.1080/15391523.2009.10782544

SHULMAN, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher*, *15*(2), 4–14. https://doi.org/10.3102/0013189X015002004

Tarus, J. K., Gichoya, D., & Muumbo, A. (2015). Challenges of Implementing E-Learning in Kenya: A Case of Kenyan Public Universities. In *International Review of Research in Open and Distributed Learning* (Vol. 16).

Vandeyar, T. (2015). Policy intermediaries and the reform of e-Education in South Africa. *British Journal of Educational Technology*, *46*(2), 344–359. https://doi.org/10.1111/bjet.12130

Voet, M., & De Wever, B. (2017). Towards a differentiated and domain-specific view of educational technology: An exploratory study of history teachers' technology use. *British Journal of Educational Technology*, *48*(6), 1402–1413. https://doi.org/10.1111/bjet.12493